Transmitter Architecture for the Evaluation of Beamforming Schemes in the IEEE 802.11n Standard

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***Abstract*— The need for speed and reliability in wireless local area networks is constantly increasing. The IEEE 802.11n standard aims to offer better data rates and performances by combining OFDM and MIMO techniques. Transmit beamforming is one of these techniques and should allow a stronger, more reliable signal for the intended user, while reducing interference towards other users. In this paper we present the realization of an 802.11n transmitter aimed at comparing different transmit beamforming schemes.**

I. Introduction

The IEEE 802.11 standard for wireless local area networks (WLAN) is arguably the most popular broadband wireless network in the world today. The latest amendment to the standard, 802.11n [1], has recently been finalized. This amendment offers yet higher data rates and more robust communications by combining multiple antenna techniques (MIMO) with orthogonal frequency division multiplexing (OFDM).

In this paper we are particularly interested in one of the MIMO techniques addressed in the standard, namely transmit beamforming. Beamforming is a signal processing technique which allows directional transmission or reception of signals by applying a beampattern on the antennas. In the case of WLAN, using beamforming on the transmitter side allows for a stronger signal to reach the desired user while reducing the interference caused to other users.

Many transmit beamforming techniques have been proposed, including, but not limited to, [2], [3] and [4]. These techniques all have their strong and weak points, which have generally been studied theorically or through simulations. Although those studies present very pertinent information, it is often useful or even necessary to compare different techniques in real situations to choose the best solution and to test new improvements to the performance or to the complexity of these solutions.

It is in this optic that we present a transmitter architecture to evaluate transmit beamforming schemes in the IEEE 802.11n standard. The work presented in this paper is a transmitter architecture designed to be portable on most field programmable gate arrays (FPGA). The transmitter does not use all of the MIMO techniques addressed in the standard, but should allow the use of most transmit beamforming schemes.

II. IEEE 802.11n Standard for Wireless LAN

The IEEE 802.11n standard, [1], is an amendment to the WLAN standard which allows theoretical data rates of up to 270 Mbps in the 2.4 GHz band or 300 Mbps in the 5 GHz band. These higher rates (previous amendments were limited to 54 Mbps) are accessible through the use of MIMO techniques such as space-time block coding (STBC), spatial multiplexing and beamforming.

Among the proposed MIMO techniques, our transmitter, as seen in Fig. 1, is only designed to use beamforming. As such it does not implement every optional parameter presented in the 802.11n standard, but rather only the mandatory parameters, which are summarized in Table I. We limited our work to the 20 MHz channel format in order to limit the complexity of the transmitter and thus leave more resources on the FPGA for the beamforming algorithm we wish to test.

Note that, although there is a beamforming module in the transmitter in Fig. 1, it only applies the beamforming weights. As the objective of this implementation is to test multiple beamforming algorithms, we chose to apply the weights to each subcarrier individually, as it afforded more flexibility in the choice of the beamforming algorithm.

TABLE I
Parameters used for the transmitter

Parameter	Value
Sampling Frequency	20 MHz
Number of Sub-carriers	56 (52 data and 4 pilots)
OFDM Symbol Period	4 μs (80 samples)
Cyclic Prefix Period	0.8 μs (16 samples)
Coding Rates	1/2, 2/3, 3/4, 5/6
Modulation Schemes	BPSK, QPSK, 16-QAM and 64-QAM
Data Rates	6.5, 13, 19.5, 26, 39, 52, 58.5, 65
FFT Processor	64-points

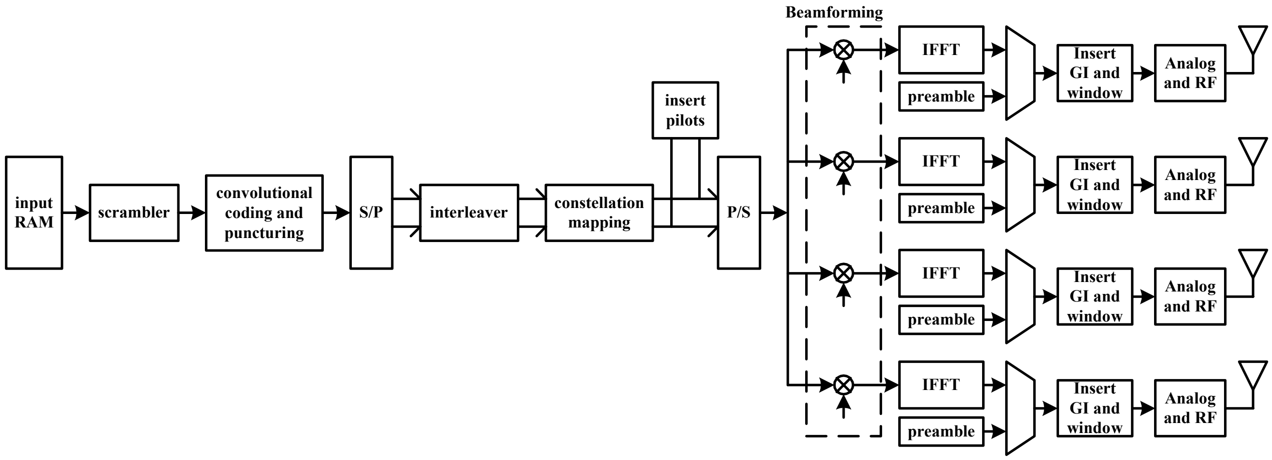

Fig. 1. IEEE 802.11n transmitter

TABLE II
IMPLEMENTATION RESULTS

	Scrambler	Encoder	Puncturing	Interleaver	Mapper	Beamforming	IFFT	Other Circuits	Total	FPGA utilization
Slices	4	4	75	359	371	0	5716	514	7043	21 %
Flip-flops	7	6	65	624	0	0	1040	316	2058	3 %
LUTs	8	8	147	0	735	0	9760	864	11522	17 %
Mult. 18x18	0	0	0	0	0	12	36	0	48	33 %

III. IMPLEMENTATION RESULTS

The transmitter presented in Fig. 1 has been modelled in VHDL and was synthesized using Xilinx's ISE design suite [5]. The target FPGA, a Xilinx Virtex-II XC2V6000 FPGA, is part of a SignalMaster development platform produced by Lyrtech [6]. Although the VHDL model is intended to be used on a Virtex-II, its synthesis has been successfully tested for Virtex-4 and Virtex-5 FPGAs. It should also be portable, with only minor modifications, to FPGAs produced by other manufacturers.

The implementation results are presented in Table II. The transmitter uses only 21% of the FPGA slices and 33% of the dedicated multipliers. Most of these ressources are used by the IFFT modules (the numbers presented in Table II for the IFFT are for the combined ressources of the 4 IFFT modules) and these modules can be reused as FFT when the receiver is implemented. The current ressource usage for the transmitter should allow enough free ressources on the FPGA to implement the receiver as well as some relatively complex transmit beamforming algorithms.

Every element of the transmitter has been analyzed individually and performs its task within determined parameters. There are still some minor integration problems preventing the transmitter be fully functional, but solving these problems should not affect the total FPGA utilization by more than 1%.

IV. CONCLUSION

In this paper we presented an 802.11n transmitter architecture realized on an FPGA. This architecture is intended to be used to test and compare transmit beamforming schemes in the WLAN context.

Implementation results indicate that our transmitter uses sufficiently few resources on the target FPGA to allow the placement of the next two elements required to test transmit beamforming, i.e. the 802.11n receiver, which should be combined with the receiver to reuse the FFT/IFFT modules, and the beamforming algorithm under test.

REFERENCES

[1] "802.11n-2009 IEEE Standard for Information Technology-Part 11 : Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment : Enhancements for Higher Throughput", IEEE Standard, 2009.

[2] J. Lorincz and D. Begusic, "Adaptive beamforming structure with STBC for IEEE 802.11n WLAN systems", *Software, Telecommunications and Computer Networks, SoftCOM 2008*, pp. 258–263, Sept. 2008.

[3] X. Sun, L. J. Cimini, D. S. Chan and L.J. Greenstein "Enhanced IEEE 802.11n quantized feedback beamforming with power allocation", *42nd Annual Conference on Information Sciences and Systems, CISS 2008*, pp. 908–912, Sept. 2008.

[4] Y. W. Liang, R. Schober and W. Gerstacker "Time-domain transmit beamforming for MIMO-OFDM systems with finite rate feedback", *IEEE Transactions on Communications*, vol. 57, no. 9, pp. 2828–2838, Sept. 2009.

[5] "The Xilinx website.", [online]. Available: http://www.xilinx.com/

[6] "The Lyrtech website.", [online]. Available: http://www.lyrtech.com/